

DESIGN FORMS FOR A CONCRETE WALL

Subcourse EN5151

EDITION B

United States Army Engineer School
Fort Leonard Wood, Missouri

5 Credit Hours

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SUBCOURSE OVERVIEW

This subcourse addresses the principles of designing wooden forms for a concrete wall. One of a carpenter's most important concerns is to ensure that all wooden forms for concrete walls are designed for strength and durability. In this subcourse you will be taught how to select the proper materials and how to space these materials to gain the desired strength. As a carpenter, you must be able to construct these wall forms to support the concrete during placement and the initial set period.

Appendix C contains an English-to-metric measurement conversion chart.

There are no prerequisites for this subcourse.

This subcourse reflects the doctrine that was current at the time this subcourse was prepared. In your own work situation, always refer to the latest official publications.

Unless otherwise stated, the masculine gender of singular pronouns is used to refer to both men and women.

TERMINAL LEARNING OBJECTIVE:

ACTION: You will learn the procedures used to design and construct wooden forms for concrete walls.

CONDITION: You will be given the material contained in this subcourse.

STANDARD: To demonstrate proficiency of this task, you must achieve a minimum score of 70 percent the subcourse examination.

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EN5151 Edition B Examination

LESSON

DESIGN FORMS FOR A CONCRETE WALL

Critical Task: 051-199-4014

OVERVIEW

LESSON DESCRIPTION:

In this lesson, you will learn what materials to select and the procedures necessary to design a wooden form for a concrete wall. This step-by-step process is presented in a step-by-step manner in this lesson.

TERMINAL LEARNING OBJECTIVE:

ACTION: You will learn to design wooden forms for concrete walls.

CONDITION: You will be given the material contained in this lesson.

STANDARD: You will correctly answer the practice exercise questions at the end of this lesson.

REFERENCES: The material contained in this lesson was derived from *Field Manual (FM) 5-34, FM 5-426, FM 5-428, Soldier Training Publication (STP) 5-12B24-SM-TG, and STP 5-51B12-SM-TG.*

INTRODUCTION

It is very important that you, as a carpenter, learn the processes involved with the designing of forms for concrete walls. The first step is to learn the different names of the various components of wooden concrete wall forms. This will enable you to determine what type and size of materials to use and where to place the specific members. The next step is to become an expert in determining the spacing of each of these supporting members. This will enable you to design a concrete form that will successfully handle concrete during the placement and set period.

PART A: MATH REVIEW

1. Like other construction tasks, designing concrete forms requires the use of a basic tool—mathematics. If used skillfully, mathematics will help you to complete this task.

2. Before you start the subcourse lesson, perform a short review of the various types of math problems that you will encounter. If you know how to add, subtract, multiply, and divide and are familiar with mathematical operation symbols, you will proceed through this lesson without any difficulty. On the other hand, if you have trouble, be patient. Examples explaining each problem are included in this lesson. Just follow the directions, keeping in mind that you learn best by

actually working out the solutions to the problems on paper. After completing the problems, go to the next paragraph to check your answers.

Problem 1. Convert 93 feet into inches.

Problem 2. How many 8-inch stakes can you cut from a piece of lumber that is 2 inches x 4 inches x 16 feet?

Problem 3. How many board feet are in a piece of lumber that is 2 inches x 6 inches x 12 feet?

Problem 4. How many 28-inch stakes can you cut from a 7-foot stake that is a piece of a 2- x 4-inch board?

Problem 5. How many square feet of plywood will you need to build a form for a small retaining wall that is to be 8 feet long x 24 inches high?

Problem 6. How many 3-foot lengths can you cut from three rolls of tie wire that are each 500 feet long?

Problem 7. How many cubic yards of concrete will it take to fill a concrete form that is 40 feet long x 34 inches wide x 6 inches deep?

Problem 8. How many cubic yards of concrete will it take to place concrete in a sidewalk form that is 35 feet long x 4 feet wide x 4 inches thick? Add a 20 percent waste factor.

Problem 9. How many cubic yards of concrete will it take to place concrete in a footer form that is 18 feet long x 12 inches wide x 6 inches thick? Add a 10 percent waste factor.

Problem 10. How many cubic yards of concrete will it take to fill a column that is 18 inches square x 12 feet high?

3. Review the following answers to the math problems given in the previous paragraph.

Problem 1.	1,116 in	$93 \times 12 = 1,116$
Problem 2.	24 stakes	$16 \times 12 = 192$ $192 \div 8 = 24$
Problem 3.	12 board ft	$2 \times 6 \times 12 = 144$ $144 \div 12 = 12$
Problem 4.	3 stakes	$12 \times 7 = 84$ $84 \div 28 = 3$
Problem 5.	32 sq ft	$8 \times 2 = 16$ 16×2 (for two sides) = 32
Problem 6.	500	$500 \times 3 = 1,500$ $1,500 \div 3 = 500$
Problem 7.	2.1 cu yd	$40 \times 34 \div 12 = 113.33$ $113.33 \times 6 \div 12 = 56.67$ $40 \times 34 = 1,360$ $1,360 \times 0.5 = 680.00$ $680.00 \div 27 = 25.19$ $56.67 \div 27 = 2.10$
Problem 8.	2.05 cu yd	$35 \times 4 = 140$ $140 \times 0.33 = 46.20$ $46.20 \div 27 = 1.71$ $1.71 \times 0.2 = 0.34$ $1.71 + 0.34 = 2.05$
Problem 9.	0.36 cu yd	$18 \times 1 = 18$ $18 \times 0.5 = 9.00$ $9.00 \div 27 = 0.33$ $0.33 \times 0.10 = 0.033$ $0.33 + 0.03 = 0.36$
Problem 10.	1 cu yd	$18 \div 12 \times 18 \div 12 \times 12 = 27$ $1.5 \times 1.5 \times 12 = 27$ $27 \div 27 = 1$

PART B: SELECT MATERIALS FOR WALL FORMS

4. Selecting the materials for wall forms is the first step in the process of designing a concrete wall. The remaining steps are covered in *Part C* of this subcourse.

Step 1. Select the appropriate materials for the wall form. To do this, you will need to understand what materials are available and which to use. Materials and sizes to select from are as follows:

- **Sheathing.** Sheathing forms the vertical surfaces of a concrete wall. The materials used for sheathing are normally 1- x 4- or 1- x 6-inch boards or 5/8- or 3/4-inch plywood. The type of sheathing selected will depend upon the type available at the supply point or on the materials-available list.
 - Sheathing can be 1 1/4-, 1 1/2-, or 2-inch-thick boards of any width; however, these sizes are used only on extra-large forms, such as seawalls or dams.
 - Sheathing should be made of plywood whenever possible because plywood can cover large areas with a single sheet. The ease of erection, economy, and strength are also reasons for selecting plywood. If available, 1/2- or 1-inch plywood may also be used.
- **Studs.** Studs add vertical rigidity to wall forms. Studs are made of 2- x 4-inch material; however, they are also available in sizes of 4 x 4 or 2 x 6 inches. For economical reasons, use 2- x 4-inch material if possible. The larger the material, the greater the load on the studs.
- **Wales.** Wales reinforce the studs when the studs extend upward more than 4 or 5 feet. Wales are structured of the same materials as studs. Usually, 2 x 4s are used because they are the most economical. However, wales may also be made of 4 x 4s or 2 x 6s. Always nail wales together to make them doubled, thereby increasing their strength. The exception to nailing wales together is to substitute a heavier material, such as a single 4 x 4 for two 2 x 4s.
- **Bracing.** Braces help stabilize wall forms. To prevent movement and maintain alignment, forms are normally braced with 2- x 4-inch material. Bracing may also be made of 4- x 4- or 2- x 6-inch materials. The choice would depend upon the size of the form and the type of material available.
- **Tie wires.** Tie wires secure the formwork against the lateral pressure of the plastic concrete. Tie wires always have double strands. Tie wires are normally made of number (No.) 8 or 9 gage annealed (soft) wire, but larger wire or barbwire may also be used. The larger the wire gage number, the smaller the diameter of the wire. Since barbwire is doubled, a smaller gage wire can be used.

Work the following problems to see how well you understand the concept covered in step 1. Following each question is a list of materials to use for the function indicated. Select the best materials for that function. The solutions to the problems are shown at the end of the lesson.

Problem 1. The best materials to use for sheathing on a wall form are—

- A. 3/4-inch plywood or 1- x 6-inch boards
- B. 2- x 4- or 2- x 10-inch boards
- C. 3- x 6- or 2- x 6-inch boards
- D. 1- x 2- or 1- x 1-inch boards

Problem 2. The best materials for studs are—

- A. 1- x 4- or 1- x 6-inch board
- B. 2- x 2-inch board or 3/4-inch plywood
- C. 2- x 6- or 2- x 4-inch board
- D. 1- x 2- or 2- x 10-inch board

Problem 3. The best materials for wales are—

- A. 1- x 6- or 1- x 10-inch board
- B. 2- x 10-inch board or 1/2-inch plywood
- C. 3- x 6- or 2- x 2-inch board
- D. 2- x 4- or 4 x 4-inch board

Problem 4. The best materials for the bracing on a wall form are—

- A. 1- x 4- or 1- x 6-inch board
- B. 2- x 10- or 1- x 2-inch board
- C. 1- x 4- or 4- x 4-inch board
- D. 4- x 4- or 2- x 4-inch board

Problem 5. The best materials for tie wires on a wall form are—

- A. 1/8-inch wire rope or No. 10 annealed wire
- B. No. 10 barbwire or No. 10 annealed wire
- C. No. 8 or No. 9 annealed wire
- D. No. 8 barbwire or No. 4 hard-drawn wire

PART C: COMPLETE THE DESIGN PROCEDURES

5. You completed step 1 of this process (*Part B*) when you determined the materials needed to construct a concrete form. Now you are ready to design the actual form and will do this by completing steps 2 through 17.

6. First, determine the rate of placing or the vertical fill rate per hour of the form. This computation involves three parts. Determine the mixer output (step 2), the plan area (step 3), and the rate of placing (step 4). Each of these steps is explained in the following pages.

Step 2. Determine the mixer output. Determine the mixer output by dividing the mixer capacity by the batch time. The unit measurement for mixer output is measured in cubic feet per hour (FPH). If you use more than one mixer, multiply the output by the number of mixers. Batch time includes loading all ingredients, mixing, and unloading. Batch time is measured in minutes. If the answer contains a decimal, round up to the next whole number. Compute as follows:

$$\text{Mixer output (cu FPH)} = \frac{\text{mixer capacity (cu ft)}}{\text{batch time (min)}} \times \frac{60 \text{ (min)}}{1 \text{ (hr)}} \times \text{number of mixers} \quad (1)$$

EXAMPLE:

Determine the mixer output if the mixer capacity is 16 cubic feet, the batch time is 7 minutes, and the mixer operates for 1 hour.

$$\text{Mixer output} = \frac{16}{7} \times \frac{60}{1} \times 1 = \frac{960}{7} = 137.14, \text{ round up to } 138 \text{ cu FPH} \quad (2)$$

Problem 6. Work the following problem to see how well you understand the concept covered in step 2. The solution to this problem is found at the end of the lesson. Determine the mixer output if the mixer capacity is 16 cubic feet and the batch time is 6 minutes with two mixers operating for 1 hour.

- A. 290 B. 308 C. 320 D. 328

Step 3. Determine the plan area. The plan area is the area enclosed by the form. Determine the plan area by multiplying the length by the width (it is measured in square feet). Compute as follows:

$$\text{Plan area (sq ft)} = \text{form } L \text{ (ft)} \times \text{form } W \text{ (ft)} \quad (3)$$

where—

L = length

W = width

EXAMPLE:

Determine the plan area for a concrete wall form that is 15 feet long x 2 feet wide x 6 feet high.

$$\text{Plan area} = 15 \times 2 = 30 \text{ sq ft} \quad (4)$$

Problem 7. Work the following problem to see how well you understand the concept covered in step 3. The solution to this problem is found at the end of the lesson. Determine the plan area for a form that is 33 feet long x 3 feet wide x 7 1/2 feet high.

- A. 30 B. 33 C. 66 D. 99

Step 4. Determine the rate of placing. Having determined the mixer output (step 2) and the plan area (step 3), it is now time to compute the rate of placing. Determine the rate of placing of concrete in the form by dividing the mixer output by the plan area. The rate of placing is measured in vertical FPH. Compute as follows:

$$R \text{ (FPH)} = \frac{\text{mixer output (cu FPH)}}{\text{plan area (sq ft)}} \quad (5)$$

where—

R = rate of placing

- If the answer contains a decimal, round to one decimal place. For example, for 1.41, use 1.4; for 1.57, use 1.6.
- The rate of placing should be kept ≤ 5 FPH for the most economical design.

EXAMPLE:

Determine the rate of placing if the mixer output is 7 cubic yards per hour ($7 \times 27 = 189$ cubic FPH) and the plan area is 15 x 2 feet.

$$R = \frac{189}{15 \times 2} = \frac{189}{30} = 6.3, \text{ use } 5 \text{ FPH} \quad (6)$$

Problem 8. Work the following problem to see how well you understand the concept covered in step 4. The solution to this problem is found at the end of the lesson. Determine the rate of placing if the mixer output is 7 cubic yard per hour (189 cubic FPH) and the plan area is 33 x 3 feet.

- A. 0.8 B. 1.9 C. 2.3 D. 3.1

Step 5. Determine the concrete placing temperature. Determine the concrete placing temperature by making a reasonable estimate of the placing temperature of the concrete. During the various seasons of the year, you will have to consider the ambient (environmental) temperature. The optimum concrete temperatures are 55° to 73°F. If the

temperature is too cold, heated aggregate and warm water are used to bring the concrete temperature up to an acceptable level. If the temperature is too hot, ice water may have to be used. The air temperature is normally 10°F above the concrete temperature. You will be performing this step as you proceed through step 6.

Step 6a. Determine the maximum concrete pressure. Estimate the concrete temperature (step 5) first. Then refer to *Figure 1*. Use a straight edge to be as accurate as possible when using the graph. Compute as follows:

- Enter the bottom of the graph at the position where your rate of placing is located.
- Move up vertically until you intersect the correct temperature curve. Estimate as closely to the temperature range as possible.
- Move to the far left side of the graph and estimate as closely as possible to the correct pressure number. It reads 100 pounds per square foot (psf). This number is the maximum concrete pressure.

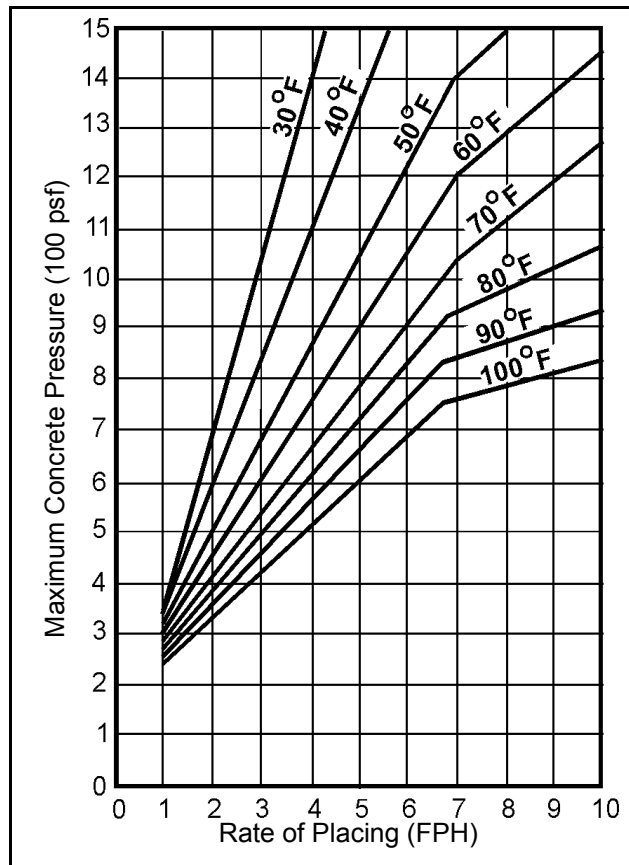


Figure 1. Maximum Concrete Pressure Graph

EXAMPLE:

Determine the maximum concrete pressure if the rate of placing is 2.5 FPH and the concrete temperature is 60°F.

500 psf

Step 6b. For a more precise determination of maximum concrete pressure, compute as follows:

$$\text{Maximum concrete pressure} = 150 + \frac{9,000R}{\text{Temperature (degrees Fahrenheit)}} \quad (7)$$

NOTE: This formula is used in place of *Figure 1* when determining maximum concrete pressure throughout this subcourse and in the examination.

EXAMPLE:

Determine the maximum concrete pressure if the rate of placing is 2.5 FPH and the concrete temperature is 60°F.

525 psf

$$\text{Maximum concrete pressure} = 150 + \frac{9,000 \times 2.5}{60} = 150 + 375 = 525 \text{ psf} \quad (8)$$

Problem 9. Work the following problem to see how well you understand the concepts covered in steps 5 and 6. The solution to this problem is found at the end of the lesson. Determine the maximum concrete pressure if the rate of placing is 1.6 FPH and the concrete temperature is 70°F.

- A. 205 B. 256 C. 300 D. 356

Problem 10. Work the following problem to see how well you understand the concepts covered in steps 5 and 6. The solution to this problem is found at the end of the lesson. Determine the maximum concrete pressure if the rate of placing is 1.9 FPH and the concrete temperature is 50°F.

- A. 400 B. 492 C. 500 D. 518

Step 7. Determine the maximum stud spacing. The maximum stud spacing depends on the type of sheathing used—boards or plywood. The maximum stud spacing is found by using either *Table 1* for board sheathing or *Table 2* for plywood sheathing. Use *Table 1 or 2* and compute as follows:

- Find the maximum concrete pressure in the left column. If the value is not listed, adjust the load up to the next value on the table. For example, for 340 psf, use 400 psf.

- Move to the right across the row to the column headed by the sheathing thickness being used. The intersecting number is the maximum stud spacing (in inches).

NOTE: All plywood sheathing problems and practice exercise problems use the strong-way column in *Table 2*.

EXAMPLE:

Determine the maximum stud spacing (in inches) if the maximum concrete pressure is 320 psf and the board sheathing thickness is 1 inch.

18 inches

Table 1. Maximum Stud or Joist Spacing for Support of Board Sheathing

Maximum Concrete Pressure (psf)	Nominal Thickness of Surfaced Boards			
	1"	1 1/4"	1 1/2"	2"
75	30	37	44	50
100	28	34	41	47
125	26	33	39	44
150	25	31	37	42
175	24	30	35	41
200	23	29	34	39
300	21	26	31	35
400	18	24	29	33
500	16	22	27	31
600	15	20	25	30
700	14	18	23	28
800	13	17	22	26
900	12	16	20	24
1,000	12	15	19	23
1,100	11	15	18	22
1,200	11	14	18	21
1,400	10	13	16	20
1,600	9	12	15	18
1,800	9	12	14	17
2,000	8	11	14	16
2,200	8	10	13	16
2,400	7	10	12	15
2,600	7	10	12	14
2,800	7	9	12	14
3,000	7	9	11	13

Table 2. Maximum Stud or Joist Spacing for Support of Plywood Sheathing

Maximum Concrete Pressure (psf)	Strong Way (5-Ply Sanded, Face Grain Perpendicular to the Stud)				Weak Way (5-Ply Sanded, Face Grain Parallel to the Stud)			
	1/2"	5/8"	3/4"	1" (7 ply)	1/2"	5/8"	3/4"	1" (7 ply)
75	20	24	26	31	13	18	23	30
100	18	22	24	29	12	17	22	28
125	17	20	23	28	11	15	20	27
150	16	19	22	27	11	15	19	25
175	15	18	21	26	10	14	18	24
200	15	17	20	25	10	13	17	24
300	13	15	17	22	8	12	15	21
400	12	14	16	20	8	11	14	19
500	11	13	15	19	7	10	13	18
600	10	12	14	17	6	9	12	17
700	10	11	13	16	6	9	11	16
800	9	10	12	15	5	8	11	15
900	9	10	11	14	4	8	9	15
1,000	8	9	10	13	4	7	9	14
1,100	7	9	10	12	4	6	8	12
1,200	7	8	10	11	—	6	7	11
1,300	6	8	9	11	—	5	7	11
1,400	6	7	9	10	—	5	6	10
1,500	5	7	9	9	—	5	6	9
1,600	5	6	8	9	—	4	5	9
1,700	5	6	8	8	—	4	5	8
1,800	4	6	8	8	—	4	5	8
1,900	4	5	8	7	—	4	4	7
2,000	4	5	7	7	—	—	4	7
2,200	4	5	6	6	—	—	4	6
2,400	—	4	5	6	—	—	4	6
2,600	—	4	5	5	—	—	—	5
2,800	—	4	4	5	—	—	—	5
3,000	—	—	4	5	—	—	—	5

NOTE: Use the strong-way columns for computing problems in this course.

Problem 11. Work the following problem to see how well you understand the concept covered in step 7. The solution to this problem is found at the end of the lesson. Determine the maximum stud spacing (in inches) if the maximum concrete pressure is 700 psf and the board sheathing thickness is 1 inch.

- A. 14 B. 15 C. 16 D. 21

Step 8. Determine the uniform load on a stud (ULS). Determine the ULS by multiplying the maximum concrete pressure (step 6) by the stud spacing (step 7). The ULS is measured in pounds per linear foot. Compute as follows:

$$ULS \text{ (lb/lin ft)} = \frac{\text{maximum concrete pressure (psf)} \times \text{maximum stud spacing (in)}}{12 \text{ (in/ft)}} \quad (9)$$

- Use the actual concrete pressure, not the adjusted value that was used to obtain the stud spacing in step 7.
- Carry out the answer to two decimal places.

EXAMPLE:

Determine the ULS if the maximum concrete pressure is 410 psf and the maximum stud spacing is 18 inches.

$$ULS = \frac{410 \times 18}{12} = \frac{7,380}{12} = 615.00 \text{ lb/lin ft} \quad (10)$$

Problem 12. Work the following problem to see how well you understand the concept covered in step 8. The solution to this problem is found at the end of the lesson. Determine the ULS if the maximum concrete pressure is 350 psf and the maximum stud spacing is 20 inches.

- A. 350.38 B. 560.70 C. 583.33 D. 593.35

Step 9. Determine the maximum wale spacing. Use *Table 3* and compute as follows:

- Find the uniform load in the left-hand column. If the value for the load is not listed in the table, adjust up to the next value given. For example, for 840 pounds per linear foot, use 900 pounds per linear foot.
- Move to the right across this row to the column headed by the correct size of the stud being used. The intersecting number is the maximum wale spacing.

Table 3. Maximum Wale Spacing

Uniform Load (lb/lin ft)	2" x 4"	2" x 6"	3" x 6"	4" x 4"	4" x 6"
100	60	95	120	92	131
125	54	85	110	82	124
150	49	77	100	75	118
175	45	72	93	70	110
200	42	67	87	65	102
225	40	63	82	61	97
250	38	60	77	58	92
275	36	57	74	55	87
300	35	55	71	53	84
350	32	50	65	49	77
400	30	47	61	46	72
450	28	44	58	43	68
500	27	41	55	41	65
600	24	38	50	37	59
700	22	36	46	35	55
800	21	33	43	32	51
900	20	31	41	30	48
1,000	19	30	38	29	46
1,200	17	27	35	27	42
1,400	16	25	33	25	39
1,600	15	23	31	23	36
1,800	14	22	29	22	34
2,000	13	21	27	21	32
2,200	13	20	26	20	31
2,400	12	19	25	19	30
2,600	12	19	24	18	28
2,800	11	18	23	17	27
3,000	11	17	22	17	26
3,400	10	16	21	16	25
3,800	10	15	20	15	23
4,500	9	14	18	13	21

EXAMPLE:

Find the maximum wale spacing if the uniform load is 1,560 pounds per linear foot and the studs are 2 x 6 inches.

23 inches

Problem 13. Work the following problem to see how well you understand the concept covered in step 9. The solution to this problem is found at the end of the lesson. Find the maximum wale spacing if the uniform load is 581 pounds per linear foot and the studs are 2 x 4 inches.

- A. 19 B. 22 C. 24 D. 27

Step 10. Determine the uniform load on a wale (ULW). Determine the ULW by multiplying the maximum concrete pressure (step 6) by the maximum wale spacing (step 9). The ULW is measured in pounds per linear foot. Compute as follows:

$$ULW \text{ (lb/lin ft)} = \frac{\text{maximum concrete pressure (psf)} \times \text{maximum wale spacing (in)}}{12 \text{ (in/ft)}} \quad (11)$$

- Use the actual concrete pressure, not the adjusted value that was used to obtain the wale spacing (step 9).
- Carry out the answer to two decimal places.

EXAMPLE:

Determine the ULW if the maximum concrete pressure is 550 psf and the maximum wale spacing is 20 inches.

$$ULW = \frac{550 \times 20}{12} = \frac{11,000}{12} = 916.67 \text{ lb/lin ft} \quad (12)$$

Problem 14. Work the following problem to see how well you understand the concept covered in step 10. The solution to this problem is found at the end of the lesson. Determine the ULW if the maximum concrete pressure is 350 psf and the maximum wale spacing is 26 inches.

- A. 350.83 B. 758.33 C. 780.53 D. 810.66

Step 11. Determine the tie-wire spacing based on the wale size. In step 13, you will compare the results of steps 11 and 12 to select the maximum allowable tie-wire spacing. Determine the tie-wire spacing based on the wale size by using *Table 4* and the following procedures. The sizes at the top of the table refer to the wale material being used. The table is divided into two halves—single-wale members are located on the left and double-wale members are located on the right.

- Find the ULW in the left-hand column of the table. If the value you have for this load is not listed in the table, adjust up to the next value given. For example, for 1,250 pounds per linear foot, use 1,400 pounds per linear foot.
- Move to the right across this row to either the single- or double-wale members section. Then locate the wale size being used. The intersecting number is the tie-wire spacing (in inches) based on the wale size.

EXAMPLE:

Determine the tie-wire spacing (in inches) if the ULW is 125 pounds per linear foot and 4- x 4-inch single wales are used.

82 inches

Table 4. Maximum Spacing of Supporting Members (Wales, Ties, Stringers, and 4- x 4-Inch and Larger Shores)

Uniform Load (lb/lin ft)	Supporting Member Size (in Inches)									
	Single Members					Double Members				
	2 x 4	2 x 6	3 x 6	4 x 4	4 x 6	2 x 4	2 x 6	3 x 6	4 x 4	4 x 6
100	60	95	120	92	131	85	126	143	111	156
125	54	85	110	82	124	76	119	135	105	147
150	49	77	100	75	118	70	110	129	100	141
175	45	72	93	70	110	64	102	124	96	135
200	42	67	87	65	102	60	95	120	92	131
225	40	63	82	61	97	57	89	116	87	127
250	38	60	77	58	92	54	85	109	82	124
275	36	57	74	55	87	51	81	104	78	121
300	35	55	71	53	84	49	77	100	75	118
350	32	50	65	49	77	46	72	93	70	110
400	30	47	61	46	72	43	67	87	65	102
450	28	44	58	43	68	40	63	82	61	97
500	27	41	55	41	65	38	60	77	58	92
600	24	38	50	37	59	35	55	71	53	84
700	22	36	46	35	55	32	51	65	49	77
800	21	33	43	32	51	30	47	61	46	72
900	20	31	41	30	48	28	44	58	43	68
1,000	19	30	38	29	46	27	43	55	41	65
1,200	17	27	35	27	42	25	39	50	38	59
1,400	16	25	33	25	39	23	36	46	35	55
1,600	15	23	31	23	36	21	34	43	33	51
1,800	14	22	29	22	34	20	32	41	31	48
2,000	13	21	27	21	32	19	30	39	29	46
2,200	13	20	26	20	31	18	29	37	28	44
2,400	12	19	25	19	30	17	27	36	27	42
2,600	12	19	24	18	28	17	26	34	26	40
2,800	11	18	23	17	27	16	25	33	25	39
3,000	11	17	22	17	26	15	24	32	24	38
3,400	10	16	21	16	25	14	23	30	22	35
3,800	10	15	20	15	23	14	21	28	21	33
4,500	9	14	18	13	21	12	20	25	19	30

Problem 15. Work the following problem to see how well you understand the concept covered in step 11. The solution to this problem is found at the end of the lesson. Determine the tie-wire spacing (in inches) if the uniform load is 756 pounds per linear foot and 2- x 4-inch double wales are used.

- A. 30 B. 43 C. 46 D. 72

Step 12. Determine the tie-wire spacing based on the tie-wire strength. Determine the tie-wire spacing based on the tie-wire strength by dividing the tie-breaking strength (step 12) by the ULW (step 10). Compute as follows:

$$\text{Tie-wire spacing (in)} = \frac{\text{tie-wire strength (lb)} \times 12 \text{ (in)}}{\text{ULW (lb/lin ft)}} \quad (13)$$

- If the strength of the tie wire is not known, refer to *Table 5* for the minimum breaking load for a double strand of wire.
- If the answer contains a decimal, round down to the next lower whole number. For example, for 11.4, use 11 or for 12.7, use 12.

Table 5. Average Breaking Load of Tie Material (in Pounds)

Steel Wire	
Size of Wire Gage	Minimum Breaking Load (lb) Double Strand
8	1,700
9	1,420
10	1,170
11	930
Barbwire	
Size of Wire Gage	Minimum Breaking Load (lb)
12 1/2	950
13*	660
13 1/2	950
14	650
15 1/2	850
Tie Rod	
Description	Minimum Breaking Load (lb)
Snap ties	3,000
Pencil rods	3,000
*Single-strand barbwire	

EXAMPLE:

Determine the tie-wire spacing (in inches) if the ULW is 1,250 pounds per linear foot and you are using No. 9 steel wire gage.

$$\text{Tie-wire spacing} = \frac{1,420 \times 12}{1,250} = \frac{17,040}{1,250} = 13.6, \text{ round down to } 13 \text{ in} \quad (14)$$

Problem 16. Work the following problem to see how well you understand the concept covered in step 12. The solution to this problem is found at the end of the lesson. Determine the tie-wire spacing (in inches) if the ULW is 1,200 pounds per linear foot and you are using No. 8 steel wire gage.

- A. 14 B. 16 C. 17 D. 18

Step 13. Determine the maximum tie-wire spacing. Determine the maximum tie-wire spacing by comparing the results from steps 11 and 12 and then using the smaller of the two tie-wire spacings as the maximum tie-wire spacing.

EXAMPLE:

Determine the maximum tie-wire spacing value by comparing the following measurements:

- Tie-wire spacing based on wale size = 24 inches.
- Tie-wire spacing based on wire strength = 20 inches.

Use the smaller tie-wire spacing of 20 inches for the maximum tie-wire spacing.

Problem 17. Work the following problem to see how well you understand the concept covered in step 13. The solution to this problem is found at the end of the lesson. Determine the maximum tie-wire spacing value by comparing the following measurements:

- Tie-wire spacing based on wale size = 26 inches.
- Tie-wire spacing based on wire strength = 16 inches.

Use the smaller tie-wire spacing of 16 inches for the maximum tie-wire spacing.

Step 14. Determine the location (spacing) of the ties. Now that you have obtained the maximum stud spacing (step 7) and the maximum tie-wire spacing (step 13), it is time to compare the two. The correct location of your ties must be determined to ensure that the form design has the proper strength.

NOTE: This step is performed only when using wires. If using snap ties, the spacing is found in Table 5.

Determining the location of the ties requires consideration of two factors when comparing stud spacing and tie-wire spacing:

- If the maximum tie-wire spacing is less than the maximum stud spacing, reduce the maximum stud spacing to equal the maximum tie-wire spacing and install the tie at the intersections of the studs and wales or get a stronger wire.
- If the maximum tie-wire spacing is greater than or equal to the maximum stud spacing, use the size for the maximum stud spacing and install the tie at the intersections of the studs and wales.

EXAMPLE:

Determine where the ties will be made if the—

- Maximum stud spacing is 28 inches.
- Maximum tie-wire spacing is 24 inches.

Reduce the stud spacing to 24 inches, and install the tie at the intersections of the studs and wales.

Problem 18. Work the following problem to see how well you understand the concept covered in step 14. The solution to this problem is found at the end of the lesson. Determine where the ties will be made if the—

- Maximum stud spacing is 14 inches.
- Maximum tie-wire spacing is 20 inches.

Step 15. Determine the number of studs for one side. Determine the number of studs for one side of a form by dividing the form length by the maximum stud spacing (step 7 or step 14 if the stud spacing has been reduced). Add 1 to this number. If the answer contains a decimal, round up to the next whole number. The first and last studs must be placed at the ends of the form, even though the spacing between the last two studs may be less than the maximum allowable spacing. Compute as follows:

$$\text{Number of studs} = \frac{\text{length of form (ft)} \times 12 \text{ (in)}}{\text{maximum stud spacing (in)}} + 1 \quad (15)$$

EXAMPLE:

Determine how many studs are required for one side of the form if the stud spacing is 24 inches and the form length is 28 feet.

$$\begin{aligned} \text{Number of studs} &= \frac{28 \times 12}{24} + 1 && (16) \\ &= \frac{336}{24} + 1 \\ &= 14 + 1 \\ &= 15 \text{ studs} \end{aligned}$$

Problem 19. Work the following problem to see how well you understand the concept covered in step 15. The solution to this problem is found at the end of the lesson. Determine how many studs are required for one side of the form if the stud spacing is 14 inches and the form length is 24 feet.

- A. 19 B. 20 C. 21 D. 22

Step 16. Determine the number of double wales for one side. Determine the number of double wales for one side of a form by dividing the form height by the maximum wale spacing (step 9). Wall studs over 4 feet require double wales. Compute as follows:

$$\text{Number of double wales} = \frac{\text{form height (ft)} \times 12 \text{ (in)}}{\text{maximum wale spacing (in)}} \quad (17)$$

- If the answer contains a decimal, round up to the next whole number. For example, for 11.4, use 12 or for 12.7, use 13.
- You must place the first wale one-half the maximum wale spacing up from the bottom. The remaining wales are placed at the maximum wale spacings that you previously determined (*Figure 2*).

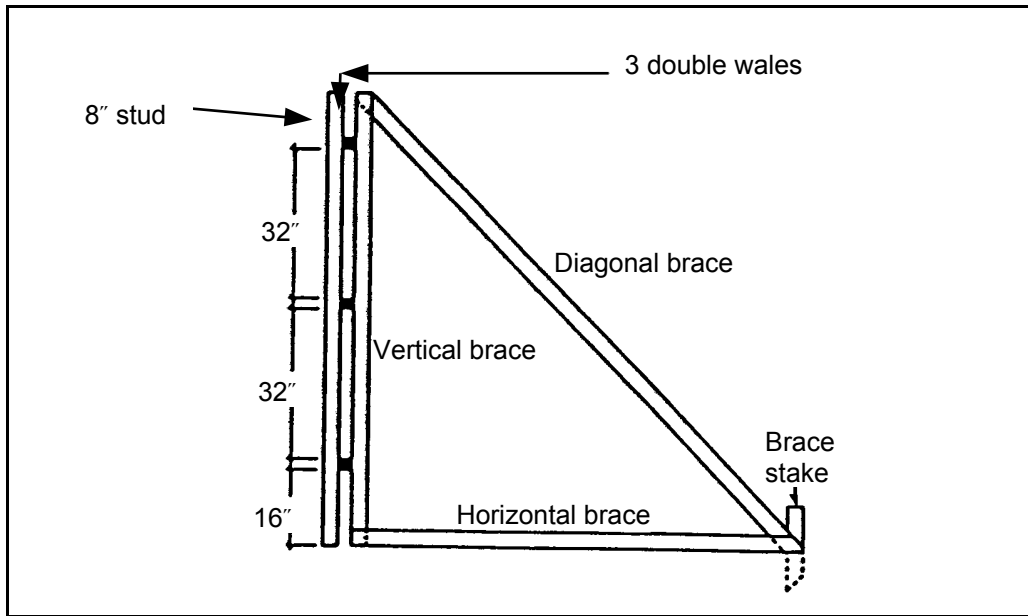


Figure 2. Double Wales on an 8-Foot Wall Form

EXAMPLE:

Determine how many wales are required for one side of the form if the wale spacing is 32 inches and the form is 8 feet high.

$$\text{Number of double wales} = \frac{8 \times 12}{32} = \frac{96}{32} = 3 \text{ wales per side} \quad (18)$$

Problem 20. Work the following problem to see how well you understand the concept covered in step 16. The solution to this problem is found at the end of the lesson. Determine how many wales are required for one side of the form if the wale spacing is 30 inches and the form is 8 feet high.

- A. 1 B. 2 C. 3 D. 4

Step 17. Determine the time required to place the concrete. Determine the time required to place the concrete by dividing the height of the form by the rate of placing (step 4). Round all answers up to the next full hour. For example, for 3.6, use 4 hours; for 5.8, use 6 hours; or for 2.1, use 3 hours. Compute as follows:

$$\text{Time to place concrete (hr)} = \frac{\text{form height (ft)}}{R \text{ (in/ft)}} \quad (19)$$

EXAMPLE:

Determine how long it will take to place concrete if the form is 20 feet high and the rate of placing is 1.2 FPH.

$$\text{Time to place concrete} = \frac{20}{1.2} = 16.66, \text{ round up to } 17 \text{ hr} \quad (20)$$

Problem 21. Work the following problem to see how well you understand the concept covered in step 17. The solution to this problem is found at the end of the lesson. Determine (in hours) how long it will take to place concrete if the form is 12 feet high and the rate of placing is 1.6 FPH.

- A. 6.3 B. 7.5 C. 8.0 D. 8.4

7. Following are the answers to the problems that were introduced in *Part B*. Review and compare to your answers.

Problem 1. A. 3/4-in plywood or 1- x 6-in boards

Problem 2 C. 2- x 6-in or 2- x 4-in board

Problem 3 D. 2- x 4-in or 4- x 4-in board

Problem 4. D. 4- x 4-in or 2- x 4-in board

Problem 5. C. No. 8 or No. 9 annealed wire

Problem 6. D. 99 sq ft

$$\text{Plan area} = 33 \times 3 = 99 \text{ sq ft}$$

Problem 7. C. 320 cu FPH

$$\text{Mixer output} = \frac{16}{6} \times \frac{60}{1} \times 2 = \frac{960}{6} \times 2 = 160 \times 2 = 320 \text{ cu FPH}$$

Problem 8. B. 1.9 FPH

$$R = \frac{189}{33 \times 3} = \frac{189}{99} = 1.9 \text{ FPH}$$

Problem 9. D. 356 psf

$$150 + \frac{9,000R}{\text{temperature}} = 150 + \frac{9,000(1.6)}{70} = 355.7, \text{ round to } 356 \text{ psf}$$

Problem 10. B. 492 psf

$$150 + \frac{9,000R}{T} = 150 + \frac{9,000(1.9)}{50} = 492 \text{ psf}$$

Problem 11. A. 14 in

Problem 12. C. 583.33 lb/lin ft

$$ULS = \frac{350 \times 20}{12} = \frac{7,000}{12} = 583.33 \text{ lb/lin ft}$$

Problem 13. C. 24 in

Problem 14. B. 758.33 lb/lin ft

$$ULW = \frac{350 \times 26}{12} = \frac{9,100}{12} = 758.33 \text{ lb/lin ft}$$

Problem 15. A. 30 in

Problem 16. C. 17 in

$$\text{Tie-wire spacing} = \frac{1,700 \times 12}{1,200} = \frac{20,400}{1,200} = 17$$

Problem 17. 16 in

Problem 18. Reduce the tie-wire spacing to 14 in

Problem 19. D. 22 studs

$$\frac{24 \times 12}{14} + 1 = \frac{288}{14} + 1 = 20.57 + 1 = 21.57, \text{ round to 22 studs}$$

Problem 20. D. 4 wales per side

$$\text{Number of double wales} = \frac{8 \times 12}{30} = \frac{96}{30} = 3.2, \text{ round up to 4 wales per side}$$

Problem 21. C. 8 hours

$$\text{Time to place concrete} = \frac{12}{1.6} = 7.5, \text{ round up to 8 hours}$$

LESSON

PRACTICE EXERCISE

Instructions: The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you have completed the exercise, check your answers with the answer key that follows. If you answer any item incorrectly, restudy that part of the lesson that contains the portion involved.

There are two situations in this exercise. Perform them step-by-step as you did during the lesson. Step 1 (materials to be selected) has been completed for you and appears in each of the problem statements.

Situation 1. You will be designing the form work for a concrete wall that is to be 140 feet long x 18 inches thick x 5 feet high. The following apply to this situation:

- You have three 16-S mixers with a 16-cubic-foot capacity. Each mixer has a batch cycle of 3 minutes.
- The concrete temperature is expected to be 80°F.
- The materials available are: 1- x 12-inch boards, 2- x 4-inch studs, 2- x 4-inch double wales, and 3,000-pound snap ties.

1. Determine the mixer output (in cubic FPH) if the mixer capacity is 16 cubic feet, batch time is 3 minutes, and the three mixers will be operating for 1 hour.

- A. 960
- B. 840
- C. 3,200
- D. 7,400

2. Determine the plan area for a concrete wall form that is 140 feet long, 5 feet high, and 18 inches thick.

- A. 140
- B. 180
- C. 210
- D. 250

3. Determine the rate of placing, in FPH.
 - A. 3.8
 - B. 4.6
 - C. 5.0
 - D. 5.6

4. Determine the concrete placing temperature.
 - A. 60
 - B. 70
 - C. 80
 - D. 90

5. Determine the maximum concrete pressure (in psf).
 - A. 600.3
 - B. 630.6
 - C. 667.5
 - D. 750.5

6. Determine the maximum stud spacing (in psf).
 - A. 13
 - B. 14
 - C. 15
 - D. 16

7. Determine the ULS (in pounds per linear foot).
 - A. 678.30
 - B. 738.51
 - C. 778.75
 - D. 828.53

8. Determine the maximum wale spacing (in inches).
- A. 20
 - B. 21
 - C. 22
 - D. 24
9. Determine the ULW (in pounds per linear foot).
- A. 1,168.13
 - B. 1,268.25
 - C. 1,325.35
 - D. 1,362.73
10. Determine the tie-wire spacing based on the wale size.
- A. 21
 - B. 23
 - C. 25
 - D. 35
11. Determine the tie-wire spacing based on the tie-wire strength.
- A. 26
 - B. 28
 - C. 32
 - D. 30
12. Determine the maximum tie-wire spacing (in inches).
- A. 21
 - B. 25
 - C. 23
 - D. 26

13. Determine the adjusted tie-wire and/or stud location (spacing).
- A. 18
 - B. 20
 - C. 25
 - D. Does not apply for snap ties
14. Determine how many studs are required for one side of the form.
- A. 121
 - B. 122
 - C. 126
 - D. 131
15. Determine how many double wales will be required for one side.
- A. 2
 - B. 3
 - C. 4
 - D. 5
16. Determine the time required to place the concrete (in hours).
- A. 0.5
 - B. 1.0
 - C. 1.5
 - D. 2.0

Situation 2. You will be designing the form work for a concrete wall that is to be 92 feet long x 12 inches thick x 6 1/2 feet high. The following apply to this problem:

- You will have one M919 mobile mixer with a 27-cubic-foot capacity. The mixer has a 1-cubic-yard batch cycle for every 4 minutes.
- The concrete temperature is expected to be 50°F.
- The materials available are: 5/8-inch-plywood sheathing, 2- x 4-inch lumber for studs, 4- x 4-inch lumber for double wales, and No. 9 wire for ties.

17. Determine the total mixer output (in cubic FPH) if the mixer capacity is 27 cubic feet (1 cubic yard) with a batching time of 4 minutes and is operating for 1 hour.

- A. 310
- B. 405
- C. 435
- D. 450

18. Determine the plan area (in square feet) for a concrete wall form that is 92 feet long x 12 inches thick x 6 1/2 feet high.

- A. 46
- B. 92
- C. 112
- D. 598

19. Determine the rate of placing (in FPH).

- A. 3.8
- B. 4.4
- C. 4.6
- D. 5.6

20. Determine the concrete temperature.
- A. 50
 - B. 60
 - C. 70
 - D. 80
21. Determine the maximum concrete pressure (in psf).
- A. 667
 - B. 750
 - C. 842
 - D. 942
22. Determine the maximum stud spacing (in psf).
- A. 6
 - B. 7
 - C. 8
 - D. 9
23. Determine the ULS (in pounds per linear foot).
- A. 678.51
 - B. 706.50
 - C. 738.54
 - D. 828.52
24. Determine the maximum wale spacing (in inches).
- A. 20
 - B. 21
 - C. 22
 - D. 24

25. Determine the ULW (in pounds per linear foot).
- A. 1,325.53
 - B. 1,468.50
 - C. 1,568.50
 - D. 1,648.51
26. Determine the tie-wire spacing based on the wale size.
- A. 30
 - B. 31
 - C. 32
 - D. 33
27. Determine the tie-wire spacing based on the tie-wire strength.
- A. 10
 - B. 11
 - C. 12
 - D. 14
28. Determine the maximum tie-wire spacing (in inches).
- A. 8
 - B. 9
 - C. 10
 - D. 11
29. Determine the adjusted tie-wire and/or stud location (spacing) (in inches).
- A. 6
 - B. 8
 - C. 9
 - D. 10

30. Determine how many studs are required for one side of the form.
- A. 120
 - B. 121
 - C. 124
 - D. 126
31. Determine how many double wales will be required for one side.
- A. 2
 - B. 3
 - C. 4
 - D. 5
32. Determine the time required to place the concrete (in hours).
- A. 0.5
 - B. 1.0
 - C. 1.5
 - D. 2.0

LESSON
PRACTICE EXERCISE
ANSWER KEY AND FEEDBACK

1. Determine the mixer output (in cubic FPH) if the mixer capacity is 16 cubic feet, batch time is 3 minutes, and the three mixers will be operating for 1 hour.

 A. 960 (step 2)

B. 840

C. 3,200

D. 7,400

2. Determine the plan area for a concrete wall form that is 140 feet long, 5 feet high, and 18 inches thick.

A. 140

B. 180

 C. 210 (step 3)

D. 250

3. Determine the rate of placing, in FPH.

A. 3.8

 B. 4.6 (step 4)

C. 5.0

D. 5.6

4. Determine the concrete placing temperature.

A. 60

B. 70

 C. 80 (Problem 1 statement and step 5)

D. 90

5. Determine the maximum concrete pressure (in psf).
- A. 600.3
 - B. 630.6
 - C. 667.5 (step 6b)
 - D. 750.5
6. Determine the maximum stud spacing (in psf).
- A. 13
 - B. 14 (step 7)
 - C. 15
 - D. 16
7. Determine the ULS (in pounds per linear foot).
- A. 678.30
 - B. 738.51
 - C. 778.75 (step 8)
 - D. 828.53
8. Determine the maximum wale spacing (in inches).
- A. 20
 - B. 21 (step 9)
 - C. 22
 - D. 24
9. Determine the ULW (in pounds per linear foot).
- A. 1,168.13 (step 10)
 - B. 1,268.25
 - C. 1,325.35
 - D. 1,362.73

10. Determine the tie-wire spacing based on the wale size.
- A. 21
 - B. 23
 - C. 25 (step 11)
 - D. 35
11. Determine the tie-wire spacing based on the tie-wire strength.
- A. 26
 - B. 28
 - C. 32
 - D. 30 (step 12)
12. Determine the maximum tie-wire spacing (in inches).
- A. 21
 - B. 25 (step 13)
 - C. 23
 - D. 26
13. Determine the adjusted tie-wire and/or stud location (spacing).
- A. 18
 - B. 20
 - C. 25
 - D. Does not apply for snap ties (step 14 note)
14. Determine how many studs are required for one side of the form.
- A. 121 (step 15)
 - B. 122
 - C. 126
 - D. 131

15. Determine how many double wales will be required for one side.
- A. 2
 - B. 3 (step 16)
 - C. 4
 - D. 5
16. Determine the time required to place the concrete (in hours).
- A. 0.5
 - B. 1.0
 - C. 1.5
 - D. 2.0 (step 17)
17. Determine the total mixer output (in cubic FPH) if the mixer capacity is 27 cubic feet (1 cubic yard) with a batching time of 4 minutes and is operating for 1 hour.
- A. 310
 - B. 405 (step 2)
 - C. 435
 - D. 450
18. Determine the plan area (in square feet) for a concrete wall form that is 92 feet long x 12 inches thick x 6 1/2 feet high.
- A. 46
 - B. 92 (step 3)
 - C. 112
 - D. 598

19. Determine the rate of placing (in FPH).
- A. 3.8
 - B. 4.4 (step 4)
 - C. 4.6
 - D. 5.6
20. Determine the concrete temperature.
- A. 50 (Problem 2 statement and step 5)
 - B. 60
 - C. 70
 - D. 80
21. Determine the maximum concrete pressure (in psf).
- A. 667
 - B. 750
 - C. 842
 - D. 942 (step 6b)
22. Determine the maximum stud spacing (in psf).
- A. 6
 - B. 7
 - C. 8
 - D. 9 (step 7)
23. Determine the ULS (in pounds per linear foot).
- A. 678.51
 - B. 706.50 (step 8)
 - C. 738.54
 - D. 828.52

24. Determine the maximum wale spacing (in inches).
- A. 20
 - B. 21 (step 9)
 - C. 22
 - D. 24
25. Determine the ULW (in pounds per linear foot).
- A. 1,325.53
 - B. 1,468.50 (step 10)
 - C. 1,568.50
 - D. 1,648.51
26. Determine the tie-wire spacing based on the wale size.
- A. 30
 - B. 31
 - C. 32
 - D. 33 (step 11)
27. Determine the tie-wire spacing based on the tie-wire strength.
- A. 10
 - B. 11 (step 12)
 - C. 12
 - D. 14
28. Determine the maximum tie-wire spacing (in inches).
- A. 8
 - B. 9
 - C. 10
 - D. 11 (step 13)

29. Determine the adjusted tie-wire and/or stud location (spacing) (in inches).
- A. 6
 - B. 8
 - C. 9 (step 14)
 - D. 10
30. Determine how many studs are required for one side of the form.
- A. 120
 - B. 121
 - C. 124 (step 15)
 - D. 126
31. Determine how many double wales will be required for one side.
- A. 2
 - B. 3
 - C. 4 (step 16)
 - D. 5
32. Determine the time required to place the concrete (in hours).
- A. 0.5
 - B. 1.0
 - C. 1.5
 - D. 2.0 (step 17)

APPENDIX A
LIST OF COMMON ACRONYMS

/	per
cu	cubic
EN	engineer
F	Fahrenheit
FM	field manual
FPH	feet per hour
ft	foot; feet
hr	hour(s)
in	inch(es)
lb	pound(s)
lin	linear
min	minute(s)
No.	number
psf	pound(s) per square foot
R	rate of placing
SM	soldier's manual
sq	square
STP	soldier's training publication
TG	trainer's guide
ULS	uniform load on a stud
ULW	uniform load on a wale

APPENDIX B

RECOMMENDED READING LIST

The following publications provide additional information about the material in this subcourse. You do not need these materials to complete this subcourse.

FM 5-34. *Engineer Field Data*. 30 August 1999.

FM 5-426. *Carpentry*. 3 October 1995.

FM 5-428. *Concrete and Masonry*. 18 June 1998.

STP 5-12B24-SM-TG. *MOS 12B, Combat Engineer, Skill Levels 2/3/4, Soldier's Manual and Trainer's Guide*. 28 March 2003.

STP 5-51B12-SM-TG. *MOS 51B, Carpentry and Masonry Specialist, Skill Levels 1/2, Soldier's Manual and Trainer's Guide*. 23 September 2002.

APPENDIX C

METRIC CONVERSION CHART

This appendix complies with current Army directives which state that the metric system will be incorporated into all new publications. *Table C-1* is a metric conversion chart.

Table C-1. Metric Conversion Chart

English Units	Multiplied By	Metric Units
Cubic feet	0.02832	Cubic meters
Cubic yards	0.76460	Cubic meters
Degrees Fahrenheit - 32	0.55560	Degrees Celsius
Feet	0.30480	Meters
Inches	2.54000	Centimeters
Inches	0.02540	Meters
Inches	25.40010	Millimeters
Pounds	453.59000	Grams
Pounds	0.45360	Kilograms
Square feet	929.00000	Square centimeters
Yards	0.91440	Meters
Metric Units	Multiplied By	English Units
Centimeters	0.39370	Inches
Cubic meters	35.31000	Cubic feet
Cubic meters	1.30800	Cubic yards
Degrees Celsius + 17.8	1.80000	Degrees Fahrenheit
Grams	0.03527	Ounces
Kilograms	2.20460	Pounds
Meters	1.09360	Yards
Meters	3.28080	Feet
Meters	39.37000	Inches
Millimeters	0.03937	Inches
Square centimeters	0.15500	Square inches